Forensic Science International 231 (2013) 244–248

Contents lists available at SciVerse ScienceDirect

Forensic Science International

journal homepage: www.elsevier.com/locate/forsciint

Reliability of cut mark analysis in human costal cartilage: The effects of blade penetration angle and intra- and inter-individual differences

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ARTICLE INFO

Article history:
Received 9 April 2012
Received in revised form 21 March 2013
Accepted 16 May 2013
Available online 25 June 2013

Keywords:
Cut marks
Tool marks
Bone trauma
Knives
Measurements
Cartilage

ABSTRACT

Identification of tool class characteristics from cut marks in either bone or cartilage is a valuable source of data for the forensic scientist. Various animal models have been used in experimental studies for the analysis of individual and class characteristics. However, human tissue has seldom been used and it is likely to differ from that of non-humans in key aspects. This study wishes to assess how the knife's blade angle, and both intra- and inter-individual variation in cartilage samples affect the ability of costal cartilage to retain the original class characteristics of the knife, as measured microscopically by the distance between consecutive striations. The 120 cartilaginous samples used in this study originated from the ribcage of 6 male cadavers which were submitted to autopsy at the North Branch of the National Institute of Legal Medicine, in Portugal. Three different serrated knives were purchased from a large department store, and were used in the experimental cuts. Samples of costal cartilage from 2 individuals were assigned to each knife. Each individual provided 20 cartilage samples. Cartilage samples were manually cut using each of the three knives, following two motions: one straight up-and-down cutting motion and parallel and one perpendicular to the blade's teeth long axis forward cutting motion. Casts of the samples were made with Mikrosil®. Image capture and processing were performed with an Olympus stereomicroscope and its software. The blade's penetration angle and inter-individual variation were shown to affect the identification of the tool class characteristics from the striation pattern observed in a kerf wall, although this seems to be related only to the degree of calcification of the costal cartilage. Intra-individual variation does not seem to significantly affect the identification of the tool class characteristics from the striation pattern observed in a kerf wall, for the same knife following the same motion. Although this study did not quantify the degree of calcification of the cartilage, this seems to be an important source of great variation regarding the interpretation of striation pattern in cartilage.

1. Introduction

Cutting lesions are defined, from a medico-legal perspective, as those in which the length is greater than the depth of the wound [1]. Cutting lesions are also tool marks on human tissue and the American Association of Firearm and Tool Mark Examiners defines a tool mark as a mark produced when a tool, or object, is placed against another object and enough force is applied to the tool or object, so that it leaves an impression [2]. Cut wounds involve the use of an instrument whose action is exerted through at least one sharp edge and the human tissues that best retain the sharp instrument's marks are bone and cartilage.

The forensic value of cut mark analysis and particularly the identification of the features in the marks caused by sharp instruments in bone or cartilage, regardless of whether they are inflicted peri-mortem or post-mortem, is twofold [3,4]. First, the potential information which can be extracted through the detailed characterization of these tool marks allows the recognition of the weapon/instrument class that was used and, second, under special circumstances the specific individual blade that created the cut mark can also be identified. Consequently, the proper documentation and analysis of knife and saw marks do have the potential to contribute significantly to the interpretation of the criminal acts involved [3,4], be they violent injuries or death.

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http://dx.doi.org/10.1016/j.forsciint.2013.05.015

However, the identification of distinctive features in tool marks reveals particular complexities [5]. Although knife wounds are second only to ballistic injuries as the major cause of violent death in homicides, knife wound analysis has also received little attention in forensic investigation. Frustration and confusion often arise with regard to analysis and examination of tool marks, while common misconceptions regarding the analysis procedures and the disagreement between forensic scientists show the need for a standardized protocol for analysis of tool marks in bone and cartilage, so as to meet the current most demanding evidentiary standards [6].

Several experimental studies have been conducted with cut mark analysis where features such as kerf width measurements, quantification of profile parameters such as cross-sectional shape, sharpness and depths of the kerf among others are identified and extrapolated from a non-human to a human model (i.e., Refs. [2,4,7–15]). Although various animal models are widely used in experimental studies of trauma analysis, the human osseous and cartilaginous tissue are significantly different from non-human tissues. In particular, it clearly differs from the animal models most commonly used, namely porcine and bovine material. These species are fast-growing animals when compared to humans, which is reflected in the microscopic structure of the cartilage. Porcine cartilage has an increased cell density when compared to human cartilage as well as a higher proteoglycans' concentration, thus being denser. This higher density is reflected in a different collagen network architecture, which influences its role as a modulator of the tissue's mechanical properties [16]. Moreover, the animal pieces used in experimental studies are commercially obtained and often belong to young individuals, in which the cartilaginous tissue structure reflects a relatively immature stage of development and therefore its non-adult biomechanical characteristics, further compromising the results of a study of this nature. Due to all the above factors, it is often challenging to interpret the results of studies using animal models and extrapolate them to a human model.

Due to the previously described differences between human and non-human cartilage, it is of great interest and relevance to use human cartilaginous tissue in an experimental cut mark analysis model. In addition to issues related to the use of non-human models, it is noticeable from the literature that experimental cut marks were produced only holding the blade perpendicular to the sample in a forward cutting motion or in a 90° angle to the sample in a straight up-and-down cutting motion [12,17,18]. Although none of the studies discuss how it was ensured that the blade stayed 'perpendicular' or at a "90°" angle, the assessment of the influence of the variation in the blade's penetration angle is important to understand if slight variations in the blade's penetration angle affect the identification of the tool class. In addition, there is no information as to whether there are identifiable variations in cut marks between different ribs in the same individual. A further additional difficulty is whether the same cut marks can be consistently obtained from the same knife and cutting motion on different individuals. Consequently, there is little understanding about the influence of intra- and inter-individual variation in cut marks that affect the ability to identify the tool class of the blade.

The present research was designed to address the issue of the misidentification of a blade when differentiating cut marks on cartilage produced by differently serrated blades. The goal of this study is to assess how the blade's penetration angle, as well as the inter- and intra-individual differences, affect the identification of the tool class characteristics in cartilage, as measured by the distance between consecutive striations in cut mark analysis, from the striation pattern observed in a kerf wall.

2. Materials and methods

The 120 cartilaginous samples used in this study originated from the ribcage of six male cadavers, with ages between 20 and 60 years submitted to autopsy at the North Branch of the National Institute of Legal Medicine, in Portugal. Death from

Fig. 1. The three knives used in this study; (a) knife 1, a straight spine, left grounded, mixed pattern finely serrated knife; (b) knife 2, straight spine, right grounded, coarsely serrated knife and (c) knife 3, a straight spine, left grounded, finely serrated knife.